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ACCOUNTING FOR NEW FINANCIAL INSTRUMENTS

Report of the UNCTAD secretariat

SUMMARY

Current accounting and reporting practices by transnational corporations and banks may fail to capture substantial off-balance sheet financings using new financial instruments. Governments also use these instruments to manage foreign debt risk exposures which represent a significant and contributory influence upon the global derivative trade. The extremely rapid growth and the sheer magnitude of the derivative market with a lack of adequate regulations has led to speculation about whether major defaults on derivatives could lead to a chain-reaction that might threaten the solvency of the international banking system. Derivatives pose significant accounting and reporting problems which are primarily due to valuation difficulties, and are almost always reported off the balance sheet. Option pricing models have been developed to value certain derivative securities, and accountants must consider using these models. The area is very complex and specialized. Because current accounting and reporting guidelines appear to be inadequate to cope with recent developments, this area should be considered for further study by standard-setting bodies.

* E/C.10/AC.3/1994/1.

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INTRODUCTION

1. This report to the Intergovernmental Working Group of Experts on International Standards of Accounting and Reporting is based on a contribution from Professors George Thomas Friedlob and John Manville Harris, Jr. of Clemson University, Clemson, South Carolina, United States of America, and forms the basis for a review of the issues and practices surrounding the accounting for new financial instruments.

2. The financial services industry is undergoing considerable development, and many regulators and commentators are publicly expressing concern about the effectiveness of existing accounting practices and financial regulations to oversee this industry. Not only are banks involved in new financial instruments, but many other enterprises and institutions enter into complex transactions to minimize their exposures to changes in commodity prices, foreign exchange rates, interest rates and other fluctuations. As the activities of transnational corporations expand around the globe, their exposure to risks naturally increases, hence financial instruments are increasingly used to mitigate potential losses and assure that terms of a transaction can be predetermined in an increasingly uncertain world.

3. Additionally, Governments which borrow in many currencies also use financial instruments to diversify their sources of funds and to minimize costs through arbitrage transactions in international and national foreign exchange capital markets and through the issuance of hedge-structured securities. There does not seem to be any shortage of financial institutions willing to trade risks for a fee. Consequently various financial instruments have been designed to manage and trade all manner of risks.

4. Accounting for the value of these instruments is difficult and almost always done off the balance sheet. The historical cost accounting model is completely ill-equipped to deal with these complex transactions as the key to the valuation of these transactions lies in the future.

5. Conclusions on Accounting and Reporting by Transnational Corporations 1/ deals with contingent liabilities and assets. The International Accounting Standards Committee (IASC) has also issued International Accounting Standard (IAS) 5 "Information to be Disclosed in Financial Statements", IAS 10 "Contingencies and Events Occurring After the Balance Sheet Date", and IAS 30 "Disclosures in the Financial Statements of Banks and Similar Financial Institutions". However, none of these guidelines specifically address the timing, measurement and valuation techniques to be applied when accounting for new financial instruments.

6. Although the market value approach is increasingly recognized as the most appropriate estimate of the worth of many securities, often there is not an appropriate market to determine the value of these highly specialized instruments. Valuation models developed by financial economists employ sophisticated methods to value securities and should be adopted by accountants to solve this problem.

7. This report is presented in five parts: firstly, there is a summary of findings; secondly, a description of current and evolving accounting practices; thirdly, an explanation in greater detail of new financial instruments, and in particular, financial derivatives, and an identification of some of the shortcomings associated with current accounting practices; fourthly, the Black-Scholes option pricing model is introduced as a technique that accountants can use to value some derivative securities; and, lastly conclusions and recommendations.

I. SUMMARY OF FINDINGS

8. Prevailing accounting and reporting practices for new financial instruments are resulting in substantial off-balance sheet financings for many commercial and non-commercial entities. Banks play a major role in originating, dealing, and holding these instruments and consequently, are more involved than other entities. Derivative financial instruments pose significant accounting and reporting problems, primarily because of valuation difficulties. Commonly used derivative financial instruments include: (a) forward contracts, (b) futures contracts, (c) options contracts, (d) swaps, (e) swaptions, and (f) hybrid securities.

9. Derivatives are often economically equivalent to contingent claims or contingent assets. A contingency is a condition or situation which may create a net asset or a net liability but the ultimate outcome will be determined only by uncertain future events. Contingencies are particularly important to banks, because banks typically have a greater variety and volume of derivative trade than other enterprises.

10. Derivatives are financial instruments. A financial instrument is any contract that gives rise to both (a) a (recognized or unrecognized) financial asset of one enterprise and (b) a (recognized or unrecognized) financial liability or equity instrument of another enterprise.

11. Financial instruments may be classified by (a) the use to which the instrument is put or (b) the kinds of market in which they are bought, sold or originated. Markets may be classified as (a) exchange markets, in which market clearing prices are regularly reported, (b) dealer markets, in which market clearing prices are available but not regularly reported, (c) brokered markets, in which market clearing prices are not available, or (d) principal-to-principal transactions, for which a market does not exist.

12. Financial instruments can be valued by the following methods:

(a) If quoted market prices are available, financial instruments should be valued at market price;

(b) If no market prices are available, financial instruments should be valued at an estimated price based on the quoted market prices of other financial instruments with similar characteristics;

(c) If there are no other financial instruments with similar characteristics, valuation may be based on either:

(i) The risk-adjusted present value of future cash flows, or

(ii) Option pricing models.

13. Derivative financial instruments are financial assets whose value is derived from the value of another asset. A derivative instrument may be (a) standardized and traded in secondary markets or (b) a custom-tailored contract between two parties.

14. Determining the value of custom-tailored, option-like derivatives is difficult. Accounting for these derivatives is almost always done off the balance sheet. Consequently, many new derivative financial instruments pose significant problems and risks for those who must rely on financial statements for information, especially financial statement information from banking institutions.

15. The publication referred to in paragraph 1 above recommends that:

"accounting and reporting of contingent liabilities and assets should be based on the concept of prudence in respect of a contingent asset, and on the degree of the probability of payment in respect of a contingent liability.

(a) A contingent liability is a condition or situation existing at the balance-sheet date that may or may not result in loss or expenditure depending on the outcome of one or more uncertain future events. A contingent liability is disclosed in the notes to the extent that it has not been accrued by a charge in the income statement, unless the possibility of a loss is remote. Contingent liabilities resulting from specific legal obligations undertaken by the enterprise, such as guarantees or discounted bills of exchange, are disclosed in the notes to the financial statements, even though it is unlikely that a loss to the enterprise will occur.

(b) A contingent asset is a condition or situation existing at the balance-sheet date that may or may not result in a gain depending on the outcome of one or more uncertain future events. A contingent asset is disclosed in the notes if it is probable that the gain will be realized."

16. The IASC has also issued standards which deal with these financial instruments. IAS 5 recommends balance sheet disclosure and the quantification of contingencies. IAS 10 recommends accrual of contingent losses if it is probable that the loss will occur and a reasonable estimate of the amount of the loss can be made. Unfortunately, none of these pronouncements deal with the root difficulty in accounting for these transactions; that is, the most appropriate valuation technique in the absence of market values.

17. Accounting practices in this area are evolving rapidly. Significant recent developments include:

(a) The United States Financial Accounting Standards Board (FASB) Statement of Financial Accounting Standard (SFAS) 107, issued in December 1991, endorses the use of the Black-Scholes option pricing model for estimating the value of some "custom-tailored" derivative securities;

(b) IAS 30, issued in August 1990, established minimum disclosure requirement for banks and financial institutions;

(c) IASC Exposure Draft E40, Financial Instruments, is to be replaced by a revised draft, E48, which will be published on 1 January 1994, with comments due by 31 July 1994.

18. The use of the Black-Scholes option pricing model is most appropriate for custom-tailored European call options on currencies. (European call options are among the most commonly used derivatives in banking). It is also appropriate for valuing some equity and commodity limited options. In addition to estimating values, the Black-Scholes option pricing model is important because it provides insight about the general determinants of value and risk for all contingent liabilities. These include: (a) the time until the contingent claim expires, (b) any changes in value of the underlying asset, (c) the degree of uncertainty about the future value of the underlying asset, and (d) the market rate of interest.

II. CURRENT ACCOUNTING AND REPORTING PRACTICES FOR DERIVATIVES AND OTHER FINANCIAL INSTRUMENTS

A. Standard-setting activity: disclosure

19. Currently, IAS 30, Disclosures in the Financial Statements of Banks and Similar Financial Institutions, issued in August 1990, establishes minimum disclosure requirements for banks and financial institutions. An IASC publication (now in draft), "Survey of the Use and Application of International Accounting Standards", found that only 6 countries have adopted IAS 30 as a national accounting standard, 3 countries used IAS 30 as the basis for national requirements, 14 countries have developed national requirements separately which conform in all material aspects with IAS 30, 12 countries have no national requirements, but national practice generally conforms with IAS 30, 15 countries have national requirements which do not conform and 3 countries have no national requirements and national practice does not generally conform with IAS 30.

20. The survey reported that, of the major global economies, only the United States and Italy have national requirements which although developed separately, conform in all material aspects with IAS 30. France, Germany and Japan have national requirements; however, they do not conform with IAS 30. Canada and the United Kingdom of Great Britain and Northern Ireland do not have national requirements but national practice generally conforms with IAS 30.

21. The 1992 World Survey of Bank Annual Reports examined the accounting and reporting practices of 100 of the world's largest commercial banks. Using this survey, the IASC (in its Survey of the Use and Application of International Accounting Standards) compiled the following key findings which might reduce disclosure of a bank's level of risk:

(a) Many banks do not comply with IAS and only 15 refer to them in the annual report;

(b) Many banks have not yet achieved the standard of disclosure required in IAS 30;

(c) Many banks distort their results through the use of hidden reserves and excess general provisions;

(d) Many banks do not disclose sufficient information about provisioning policies;

(e) 75 per cent of the banks do not provide sensitivity analyses on interest rates and liquidity;

(f) 50 per cent of the banks surveyed provide maturity analyses of loans and deposits, but only 25 per cent provide such analyses in line with the requirements of IAS 30;

(g) Few banks disclose their involvement in securitization.

22. Clearly, the accounting disclosures for banks and similar institutions is diverse and inconsistent when dealing with this important issue.

B. Standard-setting activity: financial instruments

23. The IASC September 1991 Exposure Draft E40, "Financial Instruments", is to be replaced by a revised draft, E48, which will be published on 1 January 1994. 2/ Comments on E48 are due by 31 July 1994.

24. During the summer/fall of 1993, the IASC secretariat conducted a poll of all member bodies to determine the status of national standard-setting activities relating to financial instruments. The following summary, provided by the Canadian Institute of Chartered Accountants, is based on the responses received, and other information obtained from the financial instruments project staff.

Australia

25. The Australian Accounting Standards Board and the Public Sector Accounting Standards Board of the Australian Accounting Research Foundation (AARF) published an exposure draft on financial instruments (E59) in March, 1993 for comment by September 30, 1993. E59 is similar in scope and coverage to the proposed IAS and was developed from E40.

Belgium

26. In November, 1992, the Accounting Standards Commission published Bulletins No. 28 and 29 dealing with share options and hedging, respectively.

Canada

27. The Accounting Standards Board of the Canadian Institute of Chartered Accountants is working jointly with the IASC on financial instruments and will be considering a proposed Standard identical in most respects to that proposed in its Agenda Paper 12.

Malaysia

28. The Malaysian Institute of Accountants and Malaysian Association of Certified Public Accountants have developed a discussion paper on transferable subscription rights and warrants as the basis for a standard to be developed for this type of financial instrument.

New Zealand

29. The New Zealand Society of Accountants published its Financial Reporting Standard No. 31, Disclosure of Information About Financial Instruments, in March, 1993. It is expected that additional standards on recognition, measurement and presentation will be developed, but not in the near future.

Norway

30. A project group has been established by the Accounting Standards Board to look into the subject.

South Africa

31. The South African Institute of Chartered Accountants has published an exposure draft on accounting for portfolio investments that borrows heavily from the IASC's exposure draft, E40, and also has issued a guideline on financial future contracts.

United Kingdom of Great Britain and Northern Ireland

32. The Accounting Standards Board has outstanding two Financial Reporting Exposure Drafts (FREDs) dealing with financial instrument issues: FRED 3, Accounting for Capital Instruments and FRED 4, Reporting the Substance of Transactions.

United States of America

33. The Financial Accounting Standards Board (FASB) currently has under way a long-term, multi-phase project on financial instruments and off-balance-sheet financing issues. Some issues have been dealt with and Statements of Financial Accounting Standards (SFAS) published. The FASB is currently deliberating the treatment of hedges and securitizations and similar transfers of assets. Consideration is being given to how best to proceed with the remaining issues. The following have been published as a result of the FASB's financial instruments project:

SFAS 105	Disclosure of Information about Financial Instruments with Off-Balance-Sheet Risk and Financial Instruments with Concentrations of Credit Risk
SFAS 107	Disclosure about Fair Value of Financial Instruments
SFAS 110	Reporting by Defined Benefit Pension Plans of Investment Contracts
SFAS 114	Accounting by Creditors for Impairment of a Loan
SFAS 115	Accounting for Certain Investments in Debt and Equity Securities
Interpretation 39	Offsetting of Amounts Related to Certain Contracts
Discussion Memorandum	Distinguishing between Liability and Equity Instruments and Accounting for Instruments with Characteristics of Both
Discussion Memorandum	Recognition and Measurement of Financial Instruments Research Report - Hedge Accounting: An Exploratory Study of the Underlying Issues

Other countries

34. The Bahamas, Ghana, Hong Kong, Paraguay, Singapore, Swaziland and Zimbabwe responded to the IASC secretariat's request and indicated they have no standard-setting activity under way or anticipated in the near future. However, work is under way in Denmark on a standard on foreign currency translation and it is possible that work will be undertaken in the future on financial instruments, based on the IASC standards.

C. Standard-setting activity: private perspective

35. In July of 1993 the Group of Thirty published Derivatives: Practices and Principles, a private study conducted independent of the activities of government regulators and accounting standard setters. As part of that study, The Group of Thirty offered the following recommendations for accounting and reporting derivative securities: 3/

"Recommendation 19: Accounting Practices

International harmonization of accounting standards for derivatives is desirable. Pending the adoption of harmonized standards, the following accounting practices are recommended:

(1) Dealers should account for derivatives transactions by marking them to market, taking changes in value to income each period.

(2) End-users should account for derivatives used to manage risks so as to achieve a consistency of income recognition treatment between those instruments and the risks being managed. Thus, if the risk being managed is accounted for at cost (or, in the case of an anticipatory hedge, not yet recognized), changes in the value of a qualifying risk management instrument should be deferred until a gain or loss is recognized on the risk being managed. Or, if the risk being managed is marked to market with changes in value being taken to income, a qualifying risk management instrument should be treated in a comparable fashion.

(3) End-users should account for derivatives not qualifying for risk management treatment on a mark-to-market basis.

(4) Amounts due to and from counterparties should only be offset when there is a legal right to set off or when enforceable netting arrangements are in place.

Where local regulations prevent adoption of these practices, disclosure along these lines is nevertheless recommended.

Recommendation 20: Disclosures

Financial statements of dealers and end-users should contain sufficient information about their use of derivatives to provide an understanding of the purposes for which transactions are undertaken, the extent of the transactions, the degree of risk involved, and how the transactions have been accounted for. Pending the adoption of harmonized accounting standards, the following disclosures are recommended:

(1) Information about management's attitude to financial risks, how instruments are used, and how risks are monitored and controlled.

(2) Accounting policies.

(3) Analysis of positions at the balance sheet date.

(4) Analysis of the credit risk inherent in those positions.

(5) For dealers only, additional information about the extent of their activities in financial instruments."

III. NEW FINANCIAL INSTRUMENTS

A. Contingent assets and liabilities

36. A contingency is a condition or situation which may create either a net asset and associated gain, or a net liability and associated loss, but the ultimate outcome of the condition or situation will be determined only by uncertain future events. An example of a contingent liability and associated loss is a lawsuit against a reporting company where either the likelihood of loss or the probable amount of loss cannot be estimated.

37. Accounting for and disclosure of contingencies are particularly important issues for banks because their operating environment typically involves many types of contingencies, the total amount of which is frequently substantially larger than the total amounts of contingencies of other business entities. 4/

B. Off-balance sheet risk

38. A bank may perform actions on behalf of customers or as part of its own investment and risk management operations which affect the bank's liquidity or solvency and have a great impact on the risks to which the bank is exposed. Despite impacting the bank's risks, these actions may not result in the recognition of gains or losses on the income statement, or of assets or liabilities on the balance sheet. The IASC's IAS 30, Disclosures in the Financial Statements of Banks and Similar Financial Institutions, identifies the following conditions or situations as creating off-balance sheet items:

(a) Direct credit substitutes including general guarantees of indebtedness, bank acceptance guarantees and standby letters of credit serving as financial guarantees for loans and securities;

(b) Certain transaction-related contingencies including performance bonds, bid bonds, warranties and standby letters of credit related to particular transactions;

(c) Short-term self-liquidating trade-related contingencies arising from the movement of goods, such as documentary credits where the underlying shipment is used as security;

(d) Those sale and repurchase agreements not recognized in the balance sheet;

(e) Interest and foreign exchange rate related items including swaps, options and futures; and,

(f) Other commitments, note issuance facilities and revolving underwriting facilities.

39. In addition to these off-balance sheet items, a bank may make irrevocable commitments which can affect its liquidity, solvency, and risk of failure.

40. IAS 30 requires that banks disclose the nature and amount of irrevocable commitments to lend money, and the nature and amount of contingencies and commitments resulting from off-balance sheet items.

41. In the United States, the FASB's SFAS 107 defines off-balance-sheet risk as:

(a) A financial instrument has off-balance-sheet risk of accounting loss if the risk of accounting loss to the entity may exceed the amount recognized as an asset, if any, or if the ultimate obligation may exceed the amount that is recognized as a liability in the statement of financial position;

(b) The risk of accounting loss from a financial instrument includes:

(i) the possibility that a loss may occur from the failure of another party to perform according to the terms of a contract (credit risk);

(ii) the possibility that future changes in market prices may make a financial instrument less valuable or more onerous (market risk);

(iii) the risk of theft or physical loss.

42. SFAS 107 identifies the following financial instruments as having off-balance-sheet (OBS) risk. Credit risk is identified as CR and market risk as MR:

	Type of OBS Risk	
OBS Risk to the Issuer only	CR	MR
Put option on stock (premium paid up front)		X
Put option on interest rate contracts (premium paid up front)	X	X
Call option on stock, foreign currency, or interest rate contracts (premium paid up front)		X
Loan commitments:		
Fixed rate	X	X
Variable rate		X
Interest rate caps		X

	Type of OBS Risk	
OBS Risk to the Issuer only (cont'd)	CR	MR
Interest rate floors		X
Financial guarantees	X	
Note issuance facilities at floating rates	X	
Letters of credit (also standby letters of credit) at floating rates	X	
OBS Risk to both Issuer and Holder		
Interest rate swaps - accrual basis		X
Interest rate swaps - marked to market		X
Currency swaps		X
Financial futures contracts - hedges (marked to market and gain or loss deferred - U.S. FASB SFAS 52 or 80 accounting)		X
Financial futures contracts - non-hedges (marked to market - SFAS 52 or 80 accounting)		X
Forward contracts - hedges (marked to market and gain or loss deferred)		X
Forward contracts - non-hedges (marked to market and gain or loss recognized)		X
Forward contracts - not marked to market		X

C. Financial instruments

43. IASC Exposure Draft E40, Financial Instruments, provides the following definition of a financial instrument:

(a) A financial instrument is any contract that gives rise to both a (recognized or unrecognized) financial asset of one enterprise and a (recognized or unrecognized) financial liability or equity instrument of another enterprise.

(b) A financial asset is any asset that is:

(1) cash;

(2) a contractual right to receive cash or another financial asset from another enterprise;

(3) a contractual right to exchange financial instruments with another enterprise under conditions that are potentially favourable;

(4) an equity instrument of another enterprise.

(c) A financial liability is any liability that is a contractual obligation:

(1) to deliver cash or another financial asset to another enterprise; or

(2) to exchange financial instruments with another enterprise under conditions that are potentially unfavourable.

44. Financial instruments may be classified by the use to which the instrument is put: investing and financing versus operating and hedging. This classification is based on the intent of the holder and separates financial instruments into a category which the holder intends to hold long term (investing and financing) and a category which the holder intends to use short term (operating and hedging).

45. Financial instruments can also be classified based on the kinds of market in which they are bought, sold, or originated. The United States FASB SFAS 107, Disclosures about Fair Value of Financial Instruments, identifies four broad kinds of markets: exchange market, dealer market, brokered market and principal-to-principal market.

46. An exchange market is the most public and structured of the four, and has publicly available trading volumes and closing prices. Market clearing prices are regularly reported.

47. A dealer market is for dealers trading for their owns accounts, and provides public bid and asked prices. Market clearing prices are available but not regularly reported.

48. A brokered market is a vehicle for dealers to match buyers and sellers, and has limited public price information. Market clearing prices are generally not available.

49. A principal-to-principal market is comprised of principal-to-principal sales, with no broker or other intermediary. As such, an identifiable market does not exist and no public price information is provided.

D. Valuing financial instruments

50. Financial instruments classified by market can be broadly grouped into those which have quoted market prices and those which do not. Exchange dealers and brokered markets provide varying amounts of price information. The principal-to-principal market generally provides no price information.

51. When quoted market prices are available, financial instruments should be valued at market prices. If no market prices are available, financial

instruments should be valued at estimated prices based on the quoted market prices of other financial instruments with similar characteristics. If there are no other financial instruments with similar characteristics, valuation should be based on one of the following techniques:

(a) The present value of future cash flows;

(b) Option pricing models (such as the Black-Scholes option pricing model discussed in Section IV of this report).

E. Derivative financial instruments

52. Derivative financial instruments include a wide variety of financial assets and liabilities used in banking such as forwards, futures, and option contracts, swaps, swaptions, and hybrid securities including convertible bonds and other debt contracts with equity or income participation. In general, derivative instruments are financial assets whose value is derived from the value of another financial asset. A derivative instrument may be standardized and traded in secondary markets or it may be a custom-tailored contract between two parties. Accounting for the value of these derivative instruments is difficult and almost always done off the balance sheet.

53. In 1992, the International Swaps Dealers Association estimated that the nominal value of derivative securities traded in the Over-the-Counter (OTC) market (i.e., not listed and traded on an organized exchange) exceeded US$ 4 trillion. Multinational banks are a leading source of these derivative securities. National and international bank regulatory authorities have expressed growing concern about the accountability of these banks whose economic liabilities, whether on or off-balance sheet, are usually guaranteed in whole or in part by various Governments or their agents.

54. Regardless of the extent to which the participation of banks in the derivatives markets is or should be regulated, a more accurate measure of the effect of derivatives on the banks' assets and liabilities is needed. This is especially true, since the valuation of derivatives is often counter-intuitive to those who are used to analyzing conventional assets and liabilities. For example, while increased uncertainty about the future value of an asset will decrease the current value of the asset, its effect will increase the current value of a put or call option on that asset. (This phenomenon is explained in section IV of this report.)

Types of financial derivatives

55. The majority of derivatives can be classified as either forward contracts or option contracts. Forward contracts are agreements to either buy, sell, or exchange assets at a future date. Since the price or exchange ratio is fixed at the origination of the forward contract, its value depends upon the future value of the underlying asset. If a sufficient volume of forward contracts are standardized with respect to amounts of the underlying asset, price, and maturity, and the performance of the two parties is guaranteed by another (e.g., a clearinghouse), then the forward contracts can be traded in a secondary

market. Such exchange traded forward contracts are called futures contracts. Futures markets exist for major currencies, commodities, debt instruments (interest rates), and stock indices.

56. The values of futures are easily accounted for since daily market prices are readily available from the futures exchanges. Privately negotiated forward contracts (often called OTC forwards) do not have observable market prices and are subject to the credit and legal risks associated with non-performance by one of the parties. However, they do not present risks to banks that are substantially different from their ordinary commercial lending activities.

57. Sometimes two or more OTC forward contracts are bundled together. These combined transactions are called swaps, since they are economically similar to exchanging two or more underlying assets at some future date. For example, a simple currency swap is an agreement to exchange amounts of two currencies at a future date, which can be viewed as a bundling of two forward contracts on the separate currencies. The use of currency, interest rate, commodity, and equity swaps is widespread and growing rapidly. Most swaps involve debt instruments denominated in different currencies and featuring interest rates that are fixed for different maturities. Although the number of forward contracts bundled in a swap transaction can make it seem quite complex, the risks and valuation of such transactions are still no more difficult than what banks typically encounter when managing commercial loan portfolios.

58. Option contracts differ from forward contracts in that one party has the right but not the obligation to fulfil the contract. For example, the owner of a call (put) option has the right but not the obligation to buy (sell) an underlying asset at the specified price on a future date. The party who sells the option (often called the writer of the option) must perform at the discretion of the owner of the option. Because the writer of the option is placed at a disadvantage, the buyer of an option must pay a premium to the writer. This premium will reflect the likelihood that the future value of the underlying asset will make the option valuable to its owner. The value of the premium can fluctuate according to maturity, uncertainty, and interest rates even if the value of the underlying asset remains unchanged. A swaption is the right but not the obligation to enter into a future swap within a specified period of time.

59. As is the case for certain forward contracts, certain option contracts have been standardized with respect to maturity, amount of the underlying asset, and the exercise price, and in addition as if the performance of the writer had been guaranteed by a clearinghouse. This makes it possible to have a secondary market in these exchange traded options. Exchange traded options exist for major currencies, commodities, stocks, stock indices, and debt instruments (interest rates). There are also many exchange traded options on major futures contracts. Accounting for the value of exchange traded options is relatively straightforward, since market prices can be obtained from the exchanges.

60. Unfortunately, privately negotiated (Over-the-Counter (OTC)) options are very difficult to account for accurately. Nevertheless, the use of OTC options has grown very rapidly in recent years. This is due in part to the virtual absence of any exchange traded options with maturities over one year. Much of

the concern among regulatory authorities arises from the ability of dealers such as banks to write OTC options and treat the premiums received as income while accounting for the potential contingent claims off-balance sheet. Since the value of a premium is unobservable after origination, there have been few alternatives in the past. Recently, the Black-Scholes option pricing model has been proposed as a means of estimating the value of some contingent claims.

IV. THE BLACK-SCHOLES OPTION PRICING MODEL FOR VALUING DERIVATIVE FINANCIAL INSTRUMENTS

61. In the United States, the FASB recently issued two statements governing disclosure of off-balance sheet financing. The last of these, SFAS 107, issued in December 1991, indicated that the use of the Black-Scholes option pricing model is appropriate for estimating the value of some "custom-tailored" derivative securities.

62. Although the Black-Scholes 6/ option pricing model is commonly used in theoretical and applied finance, many financial accountants are unfamiliar with it. 7/ Application of the model in the valuation of derivative instruments is neither obvious nor without the need for professional judgement. Its use in financial accounting is not yet widespread, hence the financial accountant is often unable to rely on convention or even precedent. A basic understanding of the underlying assumptions and mechanics of the model are necessary, if financial accountants are to take advantage of the Black-Scholes model when it is appropriate and recognize its limitations when analysing financial statements that rely on its use. Many years in the future, it is likely that financial accountants will begin using some of the more complex and specialized alternative option pricing models that have been recently developed by financial economists. However, it is also likely that the Black-Scholes model will remain the appropriate standard for many derivatives that are now off-balance sheet items. Foremost among these are derivatives that can be characterized as currency call options.

63. The annex to this report presents a thorough insight and explanation of the application of the Black-Scholes model to the valuation of currency call options that are now dealt with off-balance sheet. The first portion examines the determinants of call option value and extend the analysis to the value of put options. The following portion applies the Black-Scholes model to valuing currency options and uses simulation to analyse some of the major risk characteristics of currency options. The discussion of the Black-Scholes model concludes with a brief look at some of the limitations to applying the model to other derivatives.

V. CONCLUSIONS AND RECOMMENDATIONS

64. Section II of this report describes existing international and national accounting standards which deal with financial instruments. As indicated by IASC's 1992 survey of banks' annual reports, accounting practices concerning this topic are not applied or adopted consistently. Furthermore, national accounting practices are quite diverse. This is disturbing given the

substantial volume of global trade in new financial instruments and the impact upon the international financial markets.

65. Essentially the standards and guidelines which do exist offer very little substantive direction on the most appropriate valuation methods. The somewhat piecemeal approach within the guidelines and latitude in their interpretation could be partially attributed to the recent highly publicized problems encountered within the financial services industry. The complex nature of these financial products is certainly beyond the scope of the traditional historical Advanced valuation techniques are required to deal with these sophisticated financial instruments. The Black-Scholes option pricing model is gaining acceptance in some instances as an appropriate model to be used when traditionally approaches are inadequate.

66. Current ISAR recommendations on contingent liabilities and assets do not provide appropriate guidance to assist in accounting for new financial instruments. The group may wish to consider developing guidelines which deal specifically with this topic. Additionally the group may wish to make comments on the IASC's E 48.

Notes

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2/ "E40, Financial Instruments - Progress Report", IASC Insight, May 1993, pp. 1-15, and "Financial Instruments", IASC Update, November 1993, p. 2.

3/ Paul Volker, Chairman, Global Derivatives Study Group, Derivatives: Practices and Principles, (Group of Thirty: Washington, D.C.), July 1993.

4/ American Institute of Certified Public Accountants, AICPA Professional Standards. New York: AICPA, 1993, vol. 2, paragraph 9030.20.

5/ Serge Ballanger, "Regulating the Derivatives Revolution", The Bankers Magazine, March/April 1993, pp. 54-59.

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8/ Ibid.

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Annex

USING THE BLACK-SCHOLES OPTION PRICING MODEL TO VALUE DERIVATIVE FINANCIAL INSTRUMENTS USED BY BANKS

Determinants of call option value

1. A variety of derivative securities can be modeled as call options. A call option is the right (not an obligation) to buy a specified asset at a fixed and specified price within a specified period of time. The specified price of the underlying asset is often called the exercise price or sometimes the striking or strike price. The specified period of time is the maturity of the option.

2. Options are classified according to the type of underlying asset. If the call option confers the right to purchase a number of shares of stock, it is called a stock option. A currency call option confers the right to buy an amount of a foreign currency. The underlying assets for commodity, index, and interest rate options are commodities, stock indices, and treasury debt, respectively.

3. If the right to buy the underlying asset can be exercised only at the maturity of the call option, it is called a European call option. If the right to buy the asset can be exercised prior to maturity, it is called an American call option. The value of an American call option can exceed the value of an otherwise identical European call option, if the underlying asset pays a cash distribution prior to the maturity of the option, because the owner of the American option can exercise early and obtain the underlying asset before the cash is distributed. Examples of underlying assets that pay cash distributions are stocks that pay cash dividends and bonds that pay coupon interest. Foreign currencies and commodities are examples of underlying assets that do not pay cash distributions.

4. In the absence of cash distributions, the value of otherwise identical European and American call options are equal. The ability to exercise prior to maturity has no value, since there is no cash distribution to be obtained by owning the underlying asset. In brief, one can ignore the possibility of early exercise of a call option, if the underlying asset pays no cash distributions.

Value of the call option at maturity

5. The easiest method of analysing option values is to begin by considering their value at maturity, when the owner of the option must choose whether to exercise the option to buy the underlying asset at the exercise price or to let the option expire without value. When the option matures, all relevant information needed to determine its value is known with certainty.

6. At maturity (time period t=n), the value of the call option (C_n) depends only on the exercise price (X) and the value of the underlying asset (A_n). By convention, the subscript indicates the time period at which the value is observed. There is no subscript on the exercise price, since it remains

constant in all periods. If the value of the asset exceeds the exercise price (A_n>X), the value of the option will equal the arbitrage profit that one can obtain by using the option to purchase the asset at the exercise price and then selling the asset at its current value (i.e., $C_n = A_n - X$, if A_n>X). If the underlying asset value is equal to or less than the exercise price, the option will be worthless and allowed to expire unexercised (i.e., $C_n = 0$, if A_n<=X).

7. In brief, the value of the call option can be expressed mathematically as:

$$C_n = \text{Max}[A_n-X, 0] \{1\}$$

Regardless of the value of the asset in relation to the exercise price, the value of the call option will be the maximum of either difference between the asset value and the exercise price or zero. An option can never have a negative value, since it confers on its owner a right rather than an obligation to exercise.

Value of the call option prior to maturity

8. Prior to maturity the valuation of call options is complicated by the effects of time and uncertainty. The effects of both on option values are counter-intuitive. For normal assets, delaying the receipt of the asset and/or increasing uncertainty about the future value of the asset decreases its present value. However, increases in uncertainty and/or maturity increase the value of call options.

Understanding the effect of maturity

9. By assuming that the future value of the underlying asset is known with certainty, the effect of time on the value of the call option can be isolated. The present value (M0) of money received in n periods (M_n) is determined by the following formula:

$$M0 = M_n / e^{rn}$$

where r is the continuously compounded risk free rate. Hence, the present value of the call option (C_0) assuming certain knowledge of the future underlying asset value (A_n) can be obtained from equation {1} as follows:

$$C_0 = C_n/e^{rn} = \text{Max}[A_n/e^{rn}-X/e^{rn}, 0]$$

Since A/e^{rn} is simply the present value of the underlying asset (A_0), the current value of the call option when the future value of the underlying asset is known with certainty is given by:

$$C_0 = \text{Max}[A_0-X/e^{rn}, 0] \{2\}$$

which is the current value of the asset less the present value of the exercise price when positive and zero otherwise.

10. The effect of increasing the maturity of the option is to decrease the present value of the exercise price and, hence, to increase the value of the option. In the absence of any cash distributions, one is indifferent between acquiring the underlying asset now at a price A_0 and acquiring the asset for a known price of A_n n periods in the future. The call option allows you to obtain the underlying asset by paying the exercise price (X) n periods in the future. Hence, the value of the call option equals the amount by which the current underlying asset value (A_0) exceeds the present value of the future exercise price that will be paid. The value of the call option increases, because increasing the maturity of the option defers the payment of the exercise price.

Understanding the effect of uncertainty

11. Uncertainty about the future value of the underlying asset complicates the valuation of most call options. However, several of the characteristics of option value noted under certainty still apply. The option cannot have a negative value. The value of the option decreases as its maturity decreases until it has no value, given that no other characteristics change. The value of the option depends upon the value of the underlying asset at maturity.

12. The major difference between otherwise identical options on underlying assets whose values at maturity are known or uncertain is that any uncertainty increases the value of the option. This increase in value that arises as a result of uncertainty about the future value of the underlying asset is called the option's premium. In the presence of uncertainty the premium is always positive.

13. In order to understand what gives rise to the premium, consider a call option that has an exercise price equal to the expected future value of the underlying asset. In the absence of uncertainty about the future value of the asset, the option would have no value, since the exercise price would equal the ordinary purchase price of the underlying asset. However, if there is some probability that the asset will be worth more and an equal probability that it will be worth less, then the option will have value. This value is the premium and in this case the current value of the option.

14. This value reflects the possibility that the underlying asset will be worth more than the exercise price at maturity, in which case, ownership of the option will enable the investor to purchase the option at less than its market price. In cases where the underlying asset is worth less than the asset or the same as the asset at maturity, the option will still be allowed to expire. However, more variability or uncertainty about the future value of the underlying asset serves to increase the value of the option, since it increases the possibility that the value of the asset will exceed the exercise price at maturity. This characteristic of options distinguishes them from other types of assets. For most other types of assets including derivatives such as futures and forward contracts, increasing the uncertainty about or variability of their value in the future serves to lower their current market value, because investors prefer certainty or predictability of future values. Options reverse this common sense rule; uncertainty always increases their value. Failure to recognize this counter-intuitive characteristic of options can result in serious regulatory

errors, particularly in the banking industry where the explosive growth of option-like derivatives over the past decade is typically recorded off-balance sheet.

Understanding the effect of the exercise price

15. Up to this point the effect of uncertainty has been analysed within the context of an option that has an exercise price equal tc the expected value of the asset at the maturity of the option. Brokers call option that have exercise prices equal to the value of the asset "at the money options". These are distinguished from call options with exercise prices below the value of the underlying asset ("in-the-money options") and call options with exercise prices above the value of the underlying asset ("out-of-the-money options"). The degree to which the exercise price puts a call option "in" or "out" of the money has a substantial effect on the value of the option's premium.

16. Consider the effect of raising the exercise price, while holding all other elements (asset value, rate of return, maturity, and volatility) of the call option constant (i.e., moving the option out of the money). The expected future value of the asset is now below the exercise price. Hence, the probability of the option having any value in the future is less than 50 per cent and the probability that the value of the option will be zero is greater than 50 per cent. Therefore the premium or in this case the value of the option will be less than the premium or value of the option at the money. As the exercise price rises the probability that the call option will have value in the future decreases and the premium or value of the option declines.

17. Now consider the effect of lowering the exercise price, while holding all other elements constant (moving the call option into the money). The expected future value of the asset is now above the exercise price, hence, the probability that the option will have no value is decreased. However, there are now two different situations in which the option will have value at maturity. First, the underlying asset may exceed the exercise price but still be below its expected value. Hence, the option will have value but it will be less than its expected value. Second, the underlying asset may exceed its expected value. In which case, the in option will be worth more than expected. The probability that the in-the-money option will be worth more than expected is always 50 per cent. The probability that the in-the-money option will be positive but less than expected is equal to 50 per cent less the probability that the underlying asset will be less than the exercise price.

18. In the case of in-the-money options, the premium and value of the option are not the same. The premium of an option is defined as the difference between the value of an option when the future value of the underlying asset is uncertain and the value of the option when the future value of the underlying asset is known with certainty (i.e., equation 2). The premium and the value of the option are identical in the case of out-of-the-money and at-the-money options, since under certainty the future value of the underlying asset would be less than or equal to the exercise price and their values would be zero. In-the-money options have both a premium and a certain value, which added together equal the market value of the option.

19. The distinction between the premium and value of the option is important when examining in-the-money options. The effect of lowering the exercise price is always to increase the value of the call option, since the probability that the option will have value increases as the exercise price falls. However, lowering the exercise price reduces the premium. The premium arises as a result of the 50 per cent probability that the option will have greater value than expected under certainty. The value of the premium is reduced, however, because there is a probability that the option will have a positive but lesser value than it would under certainty. As the exercise price falls the probability of option having a positive but less than expected value increases. Hence, the excess of the call option's value under uncertainty over the value under certainty (the premium) is reduced, although the value of the call option under both certainty and uncertainty increases. Also the value of the call option always increases as the current asset value increases (or equivalently, as the exercise price falls).

Determinants of put option value

20. A put option is the right to sell a specified underlying asset at a specific price within a specified period of time. This contrasts with the call option, which is a right to sell. Like call options, a put option may be either American or European depending on whether it can be exercised prior to maturity. At maturity it behaves in a manner opposite to call options. If the value of the underlying asset exceeds the exercise price at maturity, it will be allowed to expire worthless. If the exercise price exceeds the value of the underlying asset at maturity, the value of the put option will equal the difference, since the asset can be purchased at its underlying value and immediately sold at the options exercise price. Whereas increasing the maturity of a call option increases its value, increasing the maturity of a put option reduces its value, since the asset value will be expected to increase over time.

Put-call parity

21. The value of put options and call options on the same underlying asset which feature the same maturity and exercise price are closely related. Consider the following investment strategy. Purchase an underlying asset of value A_0. Sell a call option (C_0) and buy a put option (P_0) on an underlying asset, which feature the same maturity and exercise price X. At the maturity of the options, the combined investment ($A_n-C_n+P_n$) will have a value equal to the exercise price (X) regardless of the future value of the underlying asset. The combined investment will be worth either more, less, or the same as the underlying asset. If the asset value exceeds the exercise price ($A_n>X$), the put option will be worthless and the buyer of the call option will force you to sell the asset for the exercise price (X). If the asset value equals the exercise price ($A_n=X$), both the put and call option will be worthless and the asset will be sold for its value (X). If the asset value is less than the exercise price ($A_n<X$), the call option will be worthless and asset can be sold for the exercise price (X) by exercising the put option.

22. In summary, the combined value of an investment in the asset and options must be equal to the exercise price:

$$A_n - C_n + P_n = X$$

regardless of what the uncertain future value of the asset turns out to be. Hence the current value of the asset (A_0), the call option (C_0), and the put option (P_0), must equal the present value of the exercise price:

$$A_0 - C_0 + P_0 = X/e^{rn}$$

where the discount rate (r) is the risk free rate, because the future value (X) is certain (risk free). This relation is known as put call parity and can be used to value any put option in terms of its exercise price and maturity, the current value of the underlying asset, the risk free rate, and the current value of an identical call option:

$$P_0 = C_0 - A_0 + X/e^{rn} \quad (3)$$

If these current values were ever to deviate from this relationship, arbitragers could buy and sell the various parts and obtain a risk free profit. Hence, deviations from this equation are small and infrequent.

23. Note from equation (3) that the put option is a positive function of the call option. Hence, the effect of increasing uncertainty about the future value of the asset is to increase the value of the put option. Uncertainty increases the value of a put option, since it increases the probability that the underlying asset value will fall below the exercise price. Therefore the value of put options exhibit the same counter-intuitive relation to uncertainty as call options. Bank regulations which fail to properly recognize the value of off-balance sheet derivatives that feature the characteristics of put options can have serious consequences.

Valuing currency options with the Black-Scholes model

24. In the early 1970s, Fisher Black and Myron Scholes [1973] developed a model for valuing call options that estimates the effects of time and uncertainty on the premium. Their model is equivalent to the value of a call option under certainty (A_0-X/e^{rn}) adjusted by two probabilities ($N[Z_1]$ and $N[Z_2]$):

$$C_0 = (A_0)N[Z_1] - (X/e^{rn})N[Z_2] \quad (4)$$

If the future value of the underlying asset is known with certainty, these probabilities are either zero or 100 per cent, which reflects that certainty. If the probabilities are 100 per cent, equation (3) reduces to the asset value less the present value of the exercise price (A_0-X/e^{rn}). If the probabilities are zero, equation (3) reduces to zero. Hence, under certainty the Black-Scholes model is equivalent to the equation (2).

25. The two probabilities ($N[Z_1]$ and $N[Z_2]$) are cumulative standard normal density functions, which are familiar to students in introductory statistics classes. The z-scores (Z_1 and Z_2) are functions of the maturity of the option (n), the exercise price (X), the current value of the underlying asset (A_0), the

risk free rate of return (r), and the standard deviation of returns on the underlying asset (s):

$$Z_1 = \{\ln(A_0/X) + (r + s^2/2)n\}/sn^{0.5} \quad \{5\}$$

and:

$$Z_2 = Z_1 - sn^{0.5} \quad \{6\}$$

where ln() is the natural logarithm of the term enclosed in the parentheses.

26. The Black-Scholes model is well suited to the valuation of currency call options for which no market price is available. Because a currency pays no cash distributions such as interest or dividends, the Black-Scholes model is appropriate for both the European and American types of currency call options.

27. Equations {3} and {4} can be combined to obtain an expression for the value of the put option:

$$P_0 = A_0(N[Z_1]-1) - (X/e^{rn})(N[Z_2]-1) \quad \{7\}$$

since the exercise price, interest rate, maturity, and underlying asset values of both options must be the same. One easily demonstrated property of the cumulative normal probability function is:

$$N[Z]-1 = -N[-Z]$$

which follows as a consequence of symmetry in the normal probability density function. Hence, the value of the put option can be expressed as:

$$PO = (X/e^{rn})(N[-Z2]) - AO(N[-Z1]) \quad \{8\}$$

which reduces to the certain value when N[z] equals either zero or one.

28. The Black-Scholes model is well suited for estimating the value of European currency put options. However, because of the likelihood of early exercise of put options, the Black-Scholes model is only appropriate for setting a lower bound on the value of American currency put options. In the case of currency call options an investor would never exercise an American option early, since the option would be expected to increase in value as it matured. Put options on the other hand can be expected to decrease in value as they mature. Hence, the premium on an American put would exceed the premium on a European put by an amount equal to the value of the opportunity to exercise early.

Estimating the parameters of the Black-Scholes model

29. Most of the parameters in the Black-Scholes option pricing model are readily observable. The exercise price and maturity of the option are specified in the option contract. The risk free rate of interest can be proxied in most cases by the current interest rate on a government note of the same denomination and maturity as the option.

30. In the case of currency options, the current value of the underlying asset is the forward exchange rate quoted for forward currency contracts that mature at the same time as the option. Market prices for forward exchange rates are only reported for major currencies such as the British pound, United States dollar, Japanese yen, German mark, French franc, the Swiss franc, and the Italian lira. Even for these currencies the market values of forward exchange rates are only reported for a limited set of maturities (typically 1 month, 2 month, 3 month, 6 month, and 12 month).

31. For situations in which an appropriate forward rate is not available, interest rate parity provides a convenient method of estimating a market forward rate. The estimate of the value of the underlying asset (A) is given by:

$$A = S\ (1+r_f)/(1+r_d) \quad \{9\}$$

where S is the current spot rate of the currency, r_d is the interest rate on a government note of the same denomination and maturity of the option, and r_f is the interest rate on a government note of the same maturity but denominated in the currency in which the underlying currency is being priced. For example, if the call option is on the United States dollar value of the German mark and matures in one year, r_f is the rate on a one-year t-bill and r_d would be the one year Lombard rate.

32. Unfortunately, the standard deviation of return on the underlying asset is not directly observable and must be estimated from current and/or historical market prices. To estimate the standard deviation of return from historical rates of return on the underlying asset, it is necessary to make some additional assumptions. These assumptions arise as a result of using past experience as a model for future possibilities. All other things being the same, the accuracy of the estimate will improve as the number of historical observations is increased. However, in order to increase the number of observations, it is necessary to either make observations more frequently or to make them further back in time. Either method presents difficulties.

33. The further one goes back in time to obtain observations, the less likely it is that the observation correctly proxies a future possibility. For example, exchange rate changes prior to 1973 will reflect the effects of the Bretton Woods mechanism for maintaining fixed exchange rates. Changes in European exchange rates during the 1980s and early 1990s would reflect the growing effectiveness of the European Monetary System. Informed estimates of potential future volatility in exchange rates need to reflect the dramatic and unexpected collapse of the disciplines provided by Bretton Woods and the European Monetary System. Estimates of exchange rate volatilities based on distant historical prices would be far too low. These low estimates of volatility would lead to substantial underestimates of the value of any assets or liabilities that behaved similar to currency options.

34. In order to avoid these problems, one can use only the most recent historical data. However, to obtain a sufficient number of observations one must observe more frequently, such as daily or hourly. Unfortunately, frequent observations over a short period of time can also lead to substantial

underestimates of the true future volatility. For example, exchange rates are subject to the long-term influence of economic variables that change slowly or infrequently, such as interest rates and expected inflation rates. Observations of exchange rates over a stable three-month period can hardly be expected to reflect the very real possibility of large unexpected changes in the long run. It is these infrequent, low probability, large changes that present the greatest challenges to the banking system. Underestimates of the value of option-like assets and liabilities that result from underestimating exchange rate volatilities serve no one's interest.

35. For example, suppose one is estimating the value of a call option on the German mark that features an exercise price of US$ 0.60 and a maturity of six months. Assume a current Lombard rate of 6 per cent and suppose that the standard deviation of the United States dollar value of the German mark is 0.4. Using equations {5} and {6}, Z1 equals 0.0638 and Z2 equals -0.2190. Using a standard cumulative normal distribution table, N(z1) equals 0.5254 and N(z2) equals 0.04133. Using equation {4}, the value of the call option is US$ 0.0642.

36. An alternative method of estimating the volatility of the underlying asset that avoids these difficulties relies on simultaneously observed prices for both the option and the underlying asset. One simply assumes that the Black-Scholes model will generate the market price of the option. Using the currently observed values for the underlying asset, the current rate on a United States t-bill with a maturity equal to the maturity of the option, and the expiration date, maturity and exercise price of the option, one solves the Black-Scholes model iteratively with different assumed standard deviations. The standard deviation that generates a Black-Scholes model option price equal to the currently observed option price is then used as the estimate of the volatility of the underlying asset. This estimate can then be used to estimate the value of unobserved options on that same underlying asset. For underlying assets that have many different observable options traded on them, one can use an average of the implied standard deviations on the different options in order to improve the accuracy of the volatility estimate.

37. The volatility of a given currency can be determined using equations {4, 5 and 6}. Various standard deviations can be used to generate the corresponding option values. In turn these estimated volatilities can then be used to observe the value of call options of currencies for which market values are not available.

38. The primary restriction on this approach is that one must have at least one currently observable option on the underlying asset. For major currencies, there are many observable markets in London, Chicago, and Philadelphia for options of various maturities and exercise prices. However, most currencies do not have listed (hence, observable) options actively traded on them. In these cases, one can sometimes use a proxy currency. For example, many less developed countries attempt to peg their currencies to either the dollar or the pound. This allows one to use observable option prices on the dollar or pound to imply a standard deviation for that currency. This approach is hazardous, however, since such currencies are often subject to relatively infrequent but substantial changes in their pegged rates. Failure to take this into account would lead to

significant underestimates of the true volatility and hence underestimates of the true value of any option-like assets and liabilities.

Evaluating the risk characteristics of options

39. The value of an option is often very sensitive to changes in the economic variable that determine its value. The Black-Scholes model can be used to evaluate these risk characteristics for all the parameters in the model. The key parameters are the price of the underlying asset, the volatility of the underlying asset, the maturity of the option, and the market rate of interest. The sensitivities of the option's value to these parameters are known respectively as delta, gamma, theta, and rho. The degree of sensitivity to each of these parameters depends in turn on the values of the remaining parameters.

40. The following sections discuss Black-Scholes based simulations of the sensitivity characteristics of option value to each of the parameters in the model with the exception of the exercise price. Although the exercise price is a determinant of option value, it is fixed at origination and invariant throughout the life of the option.

Sensitivity to underlying asset values

41. An option's delta is defined as the change in the value of the option that results from a change in the value of the underlying asset. A point estimate of the value of delta can be obtained by taking the partial derivative of the Black-Scholes option value (equation 4) with respect to the value of the asset:

$$dC/dA = e^{-rt}\, n[z_1] \quad (10)$$

because Z_1 is a function of all the parameters in the option model. Nevertheless, some generalizations about delta can be made. Since the minimum values of e^{-rt} and $N[z_1]$ are zero, delta is always positive. Hence the value of the option always increases when the value of the underlying asset increases. Likewise, since the maximum values of e^{-rt} and $N[z_1]$ are one, delta cannot exceed one. Therefore, the value of the option can never increase by more than the increase in the value of the underlying asset.

42. Multiplying an option's delta by the ratio of the asset value over the option's value (A/C) converts the measure to an elasticity that is sometimes referred to as the option's eta. The eta of an option allows one to refer to the percentage change in the option's value that results from a percentage change in the value of the underlying asset. This elasticity varies according to the value of the underlying asset but always exceeds a value of one.

43. At differing levels of volatility (uncertainty) a call option's delta will change. At high levels of volatility, the delta of an option remains relatively constant, whereas low levels of volatility produce a more variable delta. This change in an option's delta as the asset value increases is often referred to as the option's gamma.

Sensitivity to volatility

44. The sensitivity of the option's value to the volatility of the underlying asset is known as that option's vega. An estimate of vega can be obtained by taking the partial derivative of the option's value (equation 4) with respect to the standard deviation:

$$dC/ds = Ae^{-rt}\, n[z_1]\, t^{1/2} \quad \{11\}$$

Vega is always positive, so the value of the option always increases as uncertainty about the future value of the asset increases.

Sensitivity to maturity

45. The sensitivity of the option's value to the maturity of the option is known as the option's theta. An estimate of theta can be obtained by taking the partial derivative of the option's value with respect to its maturity:

$$dC/dt = (A_0e^{-rt})n[Z_1]\ s/(2t^{1/2}) - r(A_0e^{-rt})N[Z_1] + r(X/e^{rn})N[Z_2] \quad \{12\}$$

Theta is always positive, hence the value of the option increases as its maturity increases.

Sensitivity to interest rate levels

46. The sensitivity of the option's value to the level of interest rates is known as the option's rho. An estimate of rho can be obtained by taking the partial derivative of the option's value with respect to the interest rate:

$$dC/dr = t(X/e^{rt})N[Z_2 \quad \{13\}$$

Rho is always positive. Hence, an increase in the level of interest rates always has the effect of increasing the value of the option.